Optimal allocation and sizing of Multiple Distributed generation units using Improved HSA

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Abstract: **In this paper proposes a new approach to determine the optimal location and sizing of multiple distributed generation units in a radial distribution system for loss minimization and voltage profile improvement. A single objective function is proposed to minimizing the total system power losses and optimal placement and sizing of multiple distributed generations. Improved Harmony Search algorithm is used to find the optimal location and sizing of multiple distributed generation units. The proposed method is tested on IEEE 33 bus radial distribution system. For in this paper studied two Distributed generation systems i.e., only injection of real power system and injection of both active and reactive power system. In this paper, results obtained shows that the optimal placement and sizing of multiple distributed generation units in radial distribution network reduces the total power losses and improvement in voltage profile. The results from the proposed method are compared with the earlier methods and are superior to the other existing algorithms.**

Keywords: **Distributed generation,Forward and backward sweep technique, Harmony search algorithm, optimal location and sizing, power loss.**

I.INTRODUCTION

Due to increased load demand continuously in the modern distribution system, resulting to the voltage will be reduced and the burden is increased [1]. This voltage is decreased due to the lack of sufficient reactive power. Thus to voltage profile will be improved and to avoid voltage drops, compensation of reactive power is required [2]. The reactance to resistance ratio for distribution systems is low comparing to transmission network levels though it causes power loss being increased and magnitude of bus voltage will be drop in radial distribution systems [3]. By installing the distributed generation (DG), supplied some part of the real power demand, thereby current in the lines will be reduced and in the network branches MVA also reduced. Distributed generation units are related to very small generating units installed in various buses of electric power system close to load centers. In distribution systems DG can provide various benefits for the consumers as well as for the utilities. Various benefits achieved by adding the distributed generation in distribution networks. These benefits including reducing the total power loss and voltage profiles will be improved. In addition to environmental protection, distributed generation could effectively reducing energy losses, peak demand losses and improves power system stability, power quality and power factor of the networks [4-5]. The distributed generations are basically classified in to two categories 1.Non conventional based energy sources and 2.Fossil energy sources. Non conventional based distributed generations are wind energy, photo voltaic, bio mass, co generation etc. and Fossil fuel based distributed generations are internal combustion fuel sources, fuel cells etc .

Inappropriate allocation of distributed generation means its placement and sizing leads to the fault currents is increased, voltage dipping occurs, losses being increased and the system total capital and maintenance costs increases etc. The distributed generation units installing is not so easy thus the optimally allocate and capacity of the DG units should be correctly installed [6]. Distributed generation placement is basically difficult level of optimization issue, such as for minimizations of active power and reactive power losses, line loading limits, carbon emission, voltage deviation and system stability [13]. The goal is to optimizing the sizing and location of multiple distributed generation units and subjected to constraints of maximum DG capacity and bus voltage magnitude limits. There are so many optimization techniques for optimal location and sizing of distributed generation. In, analytical approach [7] also to find out the allocation of distributed generation. In more number of the present cases particles based meta-heuristics programming methods are used for finding the optimal solutions. This includes the Genetic algorithm [8]-[9] (GA), Particle swarm optimization [9] (PSO), improved Harmony search algorithms (IHSA) etc. so many advantages of particle swarm optimization and genetic algorithm techniques but convergence criteria is not always guaranteed, so in this paper proposed Improved Harmony Search Algorithm (IHSA) is presented.

The harmony search algorithm is performed well but it has some limitations. This algorithm fails to determine the optimal solutions in some cases. Such that in view of these limitations, improvement in harmony search algorithm is presented. The proposed IHSA [11] is used to determine the DG allocation in developing optimally in the distribution system. A single objective formulation and a various constraints are presented in the paper for the allocation of DGs like in the reliability improvement, losses reduction and improving in voltage profile. The proposed IHSA can be utilized for defining the DGs in a distribution network. Finally it should be concluded that the choosing capacity of distributed generations is two parts. The first one is objectives and type of distributed generation and the second one is for finding the loss minimization and optimal allocation which is presented on this paper.

The main contribution of this paper can be summarized as follows:

1. Improved version of harmony search algorithm
2. To determine optimally locating and sizing for DG units considering for only injection of active power and both injection of active and reactive power from DG units.
3. To compare solutions obtained by proposed approach with existing methods.

This paper is organized as follows: the problem formulation and the basic concept of HS and the improved harmony search algorithm are explained in section II and section III. The proposed methodology is explained in section IV; simulation results are obtained in section V and concluding the paper in section VI.

II.PROBLEM FORMULATION

A. Types of DG

DGs can be classified in to four types based on active and reactive power injections

1. Type1: Injection of active power capable of DG.
2. Type2: Injection of reactive power capable of DG
3. Type3: Injection of both active and reactive power capable of DG
4. Type 4: Injection of real power but absorbing the reactive power capable of DG

B. Single objective problem formulation

The total active power loss in distribution system is represented by

$$PL = \sum_{j=1}^{Nb} I_j^2 * R_j \quad (1)$$

Where N_b − number of branches

j – Branch number

I_j − j^{th} branch current

R_j − j^{th} branch resistance

PL − Power Loss in distribution system.

Single objective function can be designed as

$$\min f = \frac{\sum_{j=1}^{Nb} PL_j^{with\_DG}}{\sum_{j=1}^{Nb} PL_j^{base}} \quad (2)$$

Where PL^{with_DG} − Power Loss with DG

PL^{base} − Power Loss without DG

Subject to constraints

$$S_{DG}^{min} < S_{DG} < S_{DG}^{max} \quad (3)$$

$$V_{min} < V_i < V_{max} \quad (4)$$

Where S_{DG}^{max} is75% of total S load

S_{DG}^{min} is 5% of total S load

V_{max} and V_{min} are the bus voltage magnitude limits. It is around within the range of ±5% in the total operating conditions

III.HARMONY SEARCH ALGORITHMS

Harmony search algorithm (HSA) proposed by Zong woo Geem in 2001, Harmony search was inspiring by the improvising the process of Jazz. This is also one of the meta-heuristic programming techniques. Harmony search algorithm and improved version of HSa is presented in this section.

A. Harmony Memory Search

If musician searches for a better state of harmonic memory such as process of improvement of the Jazz the harmonic search is based on the performance for the process of music. Jazz improvisation is desired to achieve, to determine the best musically harmony by just as the optimization process to determine an optimal solution as determined by the objective function.

Step1: Define objective function and initialize the harmony search algorithm parameters

Optimization problem can be designed as

Minimize f(y)

Subject to $y_{jL} < y_j < y_{jU}$ (j=1, 2, 3….n)

Where y_{jL} and y_{jU} are the lower and upper limits of the variables.

The Harmony search algorithm parameters are harmony consideration probability rate (HMCR), Harmony Memory Size (HMS), Pitch adjusting rate (PAR), bandwidth (BW), maximum improvisations (K) or terminating criterion.

Step 2: Initializing the Harmony memory size

The initialization of the harmony memory in the ranges of $[y_{jL}, y_{jU}]$ (j=1, 2, 3…n) as shown in equation

$$HM = \begin{pmatrix} y_1^1 & y_2^1 & \cdots & y_N^1 \\ y_1^2 & y_2^2 & \cdots & y_N^2 \\ \vdots & \vdots & \cdots & \vdots \\ y_1^{HMS} & y_2^{HMS} & \cdots & y_N^{HMS} \end{pmatrix} \quad (5)$$

Step3: Improvising the best Harmony memory from the old harmony memory. Generating a best Harmony y^{new} is called harmony improvisation. The best Harmony memory is defined by three steps i.e., harmony memory rate, Pitch adjustment rate, randomly selection. The following procedure as:

for each j ϵ [1,N] do
if rand ( ) ≤ HMCR then

$$y_j^{new} = y_j^i \ (i=1, 2 \ldots HMS) \ \text{\%memory consideration}$$

if rand ( ) ≤ PAR then

$$y_j^{new} = y_j^{new} \pm r \times bw \ \text{\%pitch adjustment} \qquad (6)$$

end
else

$$y_j^{new} = y_{jL} + rand(\ ) \times (y_{jU} - y_{jL}) \text{\%random selection}$$

end
end

Where y_j^{new} (j=1,2…N) is the j[th] component of y^{new}, and y_j^i is (i=1,2,…harmony size) is the j[th] component of i[th] harmony vector for in harmony memory. Both rand ( ) and r are randomly generating numbers within the range of [0, 1] and the bw is a bandwidth.

Step 4: Updating the harmony memory

After generating best harmony y^{new}, the harmony memory will be updated. If the best harmony vector y^{new} is better than the old harmony vector replaces the old harmony in the harmony memory with y^{new}.

Step 5: checking the terminating criteria

If the maximum improvisations (M) is satisfied, the algorithm is stopped otherwise go to step 3 and step 4.

B. Improvised Harmony Memory Search

An improvised Harmony Memory Search algorithm is proposed in which improvements of Pitch adjusting rate and bandwidth. In harmony search pitch adjusting rate and bandwidth all are constants, but improved harmony search updated as follows

$$PAR(m) = PAR_{min} + \left(\frac{PAR_{max} - PAR_{min}}{M} \right) m \qquad (7)$$

$$bw(m) = bw_{max} \exp \left(\frac{\log\left(\frac{bw_{min}}{bw_{max}} \right)}{M} m \right) \qquad (8)$$

Where M is maximum improvisations and m is present iteration number. PAR_{min} and PAR_{max} are the minimum and maximum pitch adjusting rate, bw_{max} and bw_{min} are the maximum bandwidth distance and minimum bandwidth distance. A very huge number of cases shows that improved harmony search conducted on improved pitch adjusting rate and bandwidth have optimization process is better than the harmony search in several cases.

IV. PROPOSED METHODOLOGY

The proposed technique based on improved harmonic search algorithm for optimal allocation and sizing of a multiple distributed generation units in a radial distribution network as follows:

Step 1: Read line data and bus data of distribution network.

Step2: Load flow analysis conducted using Forward backward sweep technique [6]; calculate the total network real power losses. Algorithm for load flow analysis as follows:

1. Read system input data [14].
2. Calculate equivalent injection of current matrix.
3. Form branch current to branch injection matrix by backward sweep technique.
4. Evaluate branch current to branch voltage matrix by forward sweep technique.
5. Form distribution load flow vector and initially iteration count is zero.
6. Increment iteration value and bus voltages will be updated.
7. If a convergence criterion is not reached go to number 6.
8. Calculate branch currents, node voltages and power loss

Step 3: Initialize harmony memory size and algorithm parameters.

Step 4: Fix the DG size maximum and minimum limits and its position. Location of distributed generation depends on consideration of number of buses in the test network

Step 5: For harmony vector each memory check the magnitude of bus voltage limits is within the range and if any exceeding the limits then the harmony is worst harmony and it replaces the best harmony vector.

Step 6: For each harmony vector calculate power loss for defining the objective function.

Step7: Perform pitch adjusting rate and distance of bandwidth and harmony consideration probability rate operations.

Step 8: The objective function vector values are arranged the minimum to maximum and remove worst harmony vector space and to modify and keep the best harmony vector values.

Step 9: Increment the iteration value by 1 and repeat the step 5 to step 8 and it is reaches to number of improvisations will be reached to maximum.

After the completion of step9, the results obtained are optimal. Finally the harmony vector values of the best harmony memory gives optimal placement and sizing of distributed generation for the given test system.

V. SIMULATION RESULTS

IEEE 33 bus radial distribution network shown in figure 1 is tested on the proposed technique, Number of branches=32, number of buses =33, bus 1 is slack bus, Base voltage =12.66 kV, base MVA=100 MVA

In MATLAB 2012 this 33 bus test network is simulated and the proposed technique has been tested and studied two study systems i.e., only injection of real power and both injection of real and reactive power whose results as shown below.

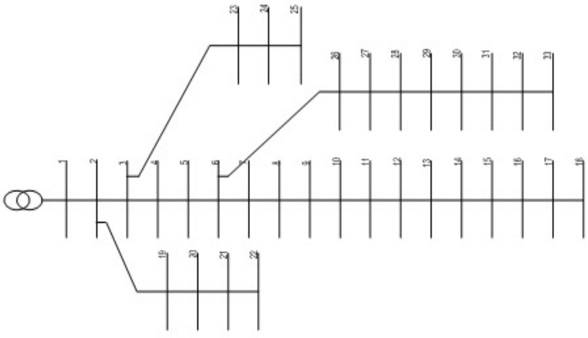

Figure1.Single line diagram of IEEE 33 bus test system

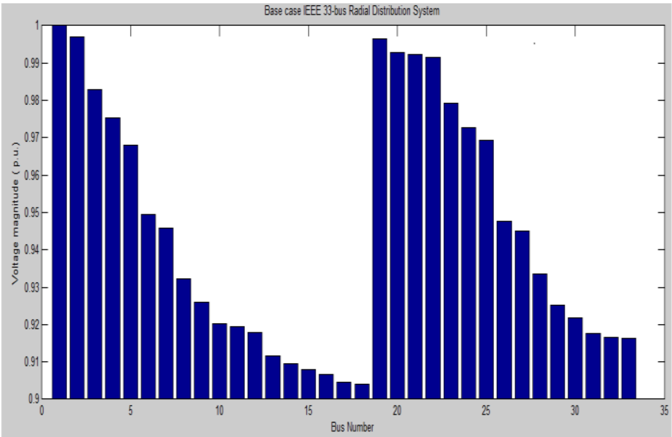

Figure 2. Voltage profile plot with out DG

Table1. IHSA parameters

Number of runs	9
Harmony memory size	50
Maximum number of improvisations	100
HMCR	0.5
Par maximum	0.9
Par minimum	0.4
Bw maximum	1
Bw minimum	0.0001

The improved harmony search algorithm parameters applied for this proposed DG placement technique for IEEE 33 bus radial distribution test network as shown in table 1.Harmony memory contains three vectors consist of placement of bus, DG active power and DG reactive power respectively. At each and every run harmony memory is value of the assessed for its objective function (2). Maximum number of improvisations contained in table 1 is reached; objective function reaches the minimum value. As per the proposed technique, 85% improvement in reducing the power losses and 15% improvement in voltage profile. Voltage profile plots with injection of active power only and both injection of active and reactive power from DG units as shown in Figure 3 and Figure 4. Total power loss reduction for only injection of active power and both real and reactive power injection from DG units as show in figure 5 and figure 6.

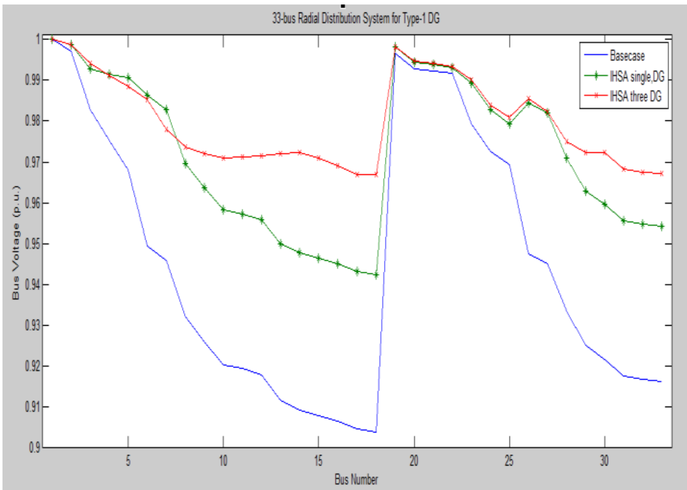

Figure3. Comparison of Voltage profile plot for type -1 DG

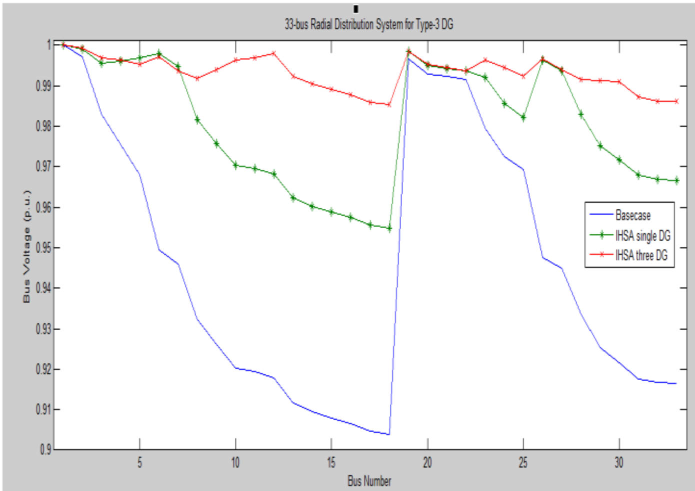

Figure4. Comparison of Voltage profile plot for type-3 DG

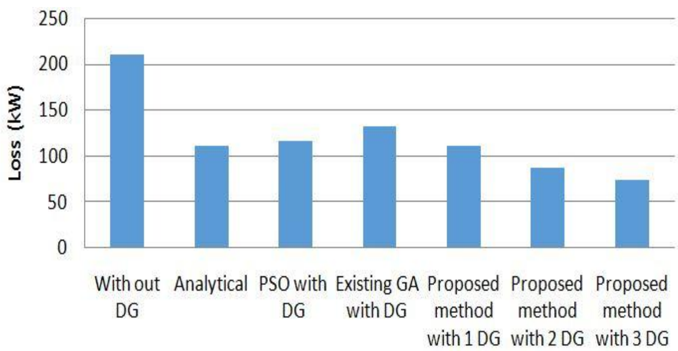

Figure 5.loss reduction of comparison for only active power injection

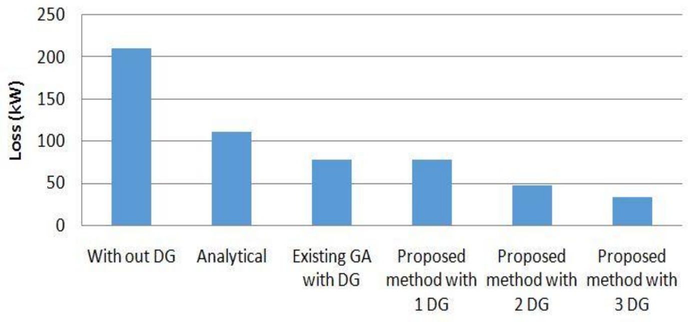

Figure 6.loss reduction of comparison for both active and reactive power injection

Study system 1: Real power injection

Optimal DG placement results for IEEE 33 bus radial distribution system by existing GA method and proposed method for only active power injection is shown in table 2. The optimal size of DG at bus 6 with single DG injection is 2.37 MW. Voltage profile improvement and loss reduction after placing the DG optimally is shown in figures 3 and 5. Without the DG placement, the bus number 18 has the magnitude of bus voltage will be lower of 0.9039 p.u and after placing a single DG the magnitude of bus voltage improved to 0.9425 and placing three DGs the voltage improved to 0.9668 p.u. Similarly the losses have reduced from 210.83 kW to 110.98 and placing three DGs losses have reduced to 73.51kW

Table2. Comparison of performance parameters for active power injection

Particulars		Analytical [7]	PSO [9]	GA [13]	Proposed method		
					Single DG	Two DG	Three DG
Optimal placement of DG		6	6	30	6	14,30	14,24,32
Optimal DG sizes	MW	2.49	2.4939	2.38	2.37	0.829@14 1.13@30	0.8@14 0.94@24 0.99@32
	Pf	Upf	Upf	Upf	Upf	Upf	Upf
Base case losses in kW		211.2	212.43	216	210.83	210.83	210.83
Losses with DG in kW		111.24	116.26	132.64	110.98	87.33	73.51
Loss savings in kW		99.96	96.17	83.36	99.85	123.50	137.32
Percentage loss reduction		47.33	45.16	38.59	47.36	58.58	65.13
Loss savings in kW per DG MW injection		40.14	38.56	35.02	42.13	148.97 109.29	171.65, 146.08 138.70

Table3. Comparison of performance parameters for real and reactive power injection

Particulars		Analytical [7]	PSO [12]	Existing GA method [13]	Proposed method		
					Single DG	Two DG	Three DG
Optimal placement of DG		6	6	30	6	12,30	12,24,32
Optimal DG sizes	MVA	2.49	3.091	1.95	1.98	1.02@12 1.3@30	0.88@12 0.78@24 1.1@32
	Pf	Upf	0.82 Lag	0.95 Lag	0.95 Lag	0.95 Lag	0.95 Lag
Base case losses in kW		211.2	211	210.97	210.83	210.83	210.83
Losses with DG in kW		111.24	68	78.413	78.20	47	33.15
Loss savings in kW		99.96	143	132.55	132.63	163.83	177.68
Percentage loss reduction		47.33	67.77	62.83	62.9	77.7	84.27
Losses savings in kW per DG injection in MVA		40.14	46.26	67.977	66.98	160.61 126.02	201.9 227.79 161.52

For single DG placing, existing GA and IHSA loss reduction yields to 38.59% and 47.36% and placing a three DGs loss reduction of 65.13% respectively.

Study system 2: Real and reactive power injection

Table 3 shows optimally placing DGs for IEEE 33 bus radial distribution system for existing GA and proposed method for injection of real and reactive power. The optimum sizing of DG at bus 6 is (1881+j618.25) kVA. The voltage profile improving and loss reduction after placing the DG optimally is shown in figures 4 and 6. After installing a single DG, the minimum bus voltage at bus number 18 have improved to 0.9549 p.u, but installing three DGs voltage profile has improved to 0.9853 p.u. Similarly by placing a single DG loss is reduced to 78.20 kW and placing a three DGs losses have reduced to 33.15 kW. For single DG placing by existing GA and IHSA loss reduction are 62.83% and 62.9% and placing a three DGs loss reduction of 84.27% respectively.

VI CONCLUSION

This paper presents a new approach to determine the optimal location and sizing of multiple distributed generation units in distribution system. The effectiveness of this approach is demonstrated on IEEE 33 bus radial distribution network. From simulation results, it can be concluded that reducing the total power loss effectively in proposed method which is better than the existing GA method. Real and reactive power injection system gives better performance than the real power injection for loss minimization and improvement in voltage profile. Finally concluded that the proposed improved harmony search algorithm (IHSA) based approach is very accurate to determining the optimal solutions. The DG placement proposed method presenting this paper considering the radial distribution network as a balanced network but in many of the distribution networks is unbalanced systems. Hence the proposed technique will be extended for unbalanced distribution networks with changing the load demand.

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